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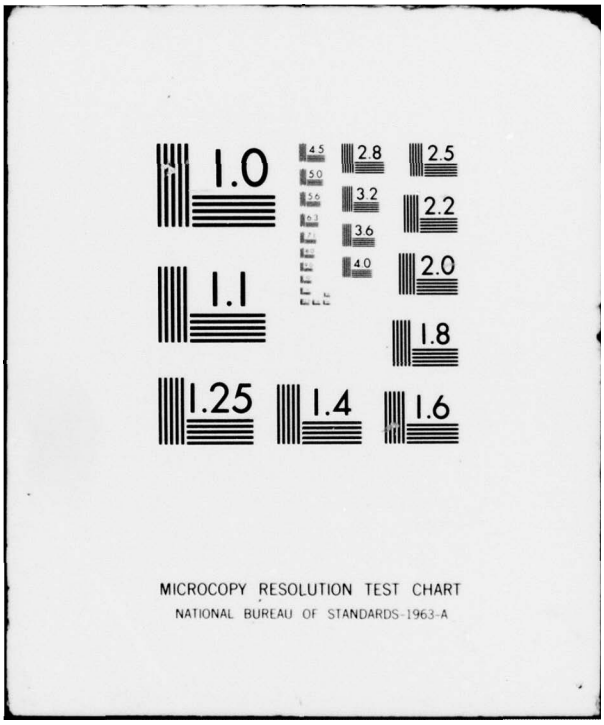
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Publication 0631-01-1-1204

Anne Arundel County
Board of Education

TELEPHONE COMMUNICATIONS STUDY

December 1972

Prepared for
ANNE ARUNDEL COUNTY
BOARD OF EDUCATION
ANNAPOLIS, MARYLAND

ARINC RESEARCH CORPORATION

Anne Arundel County
Board of Education

TELEPHONE COMMUNICATIONS STUDY

prepared for

Anne Arundel County
Board of Education
Annapolis, Maryland

December 1972

by

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Publication 0631-01-1-1204

SUMMARY

ARINC Research Corporation conducted a study of the voice communications requirements for the Anne Arundel County Board of Education during October and November 1972. The study represents the first phase of a two-phase program:

Phase I - Determination of the voice communications requirements of the Board of Education's new Riva Road facility.

Phase II - Determination of the voice communications requirements of the other Board of Education facilities (elementary schools, high schools, etc.).

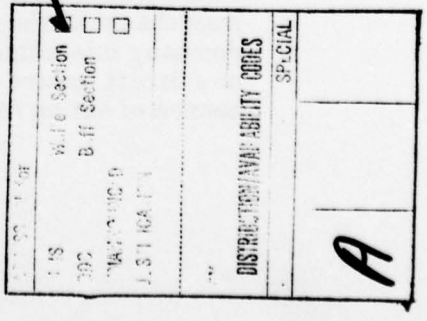
This report presents the findings of Phase I. Phase II results will be presented in a separate report.

The basic objective of the Phase I study was to find answers to three questions regarding the new Riva Road facility:

- How will the move of the Board of Education to the new Riva Road facility affect telephone-call volume?
- What configuration of trunks, switching equipments, and local extensions is required to provide adequate service?
- What type of telephone system is best for the Board of Education, and who should supply it?

During Phase I, information on the present system configuration and traffic levels was obtained from Board of Education personnel through interviews and questionnaires. The accumulated data were analyzed to project the traffic load for the new Riva Road facility. Adjustment factors were applied to the basic traffic estimate to account for such factors as busy-hour traffic peaks, seasonal variations, and expected growth. The adjusted traffic estimate was then used to determine the trunk requirements for the new facility.

The C&P Telephone Company of Maryland and two independent suppliers--International Telephone & Telegraph Company (ITT) and United Business Communications Company (UBC) -- were requested to provide detailed quotes on private branch exchanges (PBX) and direct inward - dialing systems that would satisfy the predicted trunk requirements and traffic levels for the new facility. This information was evaluated to determine the best configuration for the new Board of Education telephone communications system.



The PBX systems were eliminated because of their somewhat higher costs and their lack of many useful features offered with direct inward-dialing systems. The following three direct inward-dial systems were evaluated in detail:

- CENTREX II, supplied by the C&P Telephone Company of Maryland
- FXB-304U1, supplied by UBC
- EPABX-TE400A, supplied by ITT

The UBC alternative was eliminated because: (1) with the required telephone company interconnect charges, it would be more expensive than CENTREX II, and (2) in our judgment, it has insufficient expansion capability. The latter factor is especially critical, since the UBC system would probably operate at near peak capacity. The ITT alternative was eliminated for cost reasons also, although it did possess greater capacity and expandability than the UBC offering.

Our analysis disclosed not only that the CENTREX II system would be somewhat less expensive for the Board of Education but that the County Government could realize a saving of at least $6,000 per year by implementing a combined County Government/Board of Education CENTREX II, rather than maintaining separate systems.

ARINC Research therefore recommends that the Board of Education share with the County Government a CENTREX II system, leased from the Maryland C&P Telephone Company. A 10,000-cubic-foot space (25 x 50 x 8 feet) in the new Riva Road facility will provide adequate room for the system. No unusual site requirements are foreseen; however, the telephone company should be requested to determine the room door size required for equipment access, the lighting requirements, and the type of ducting or conduit to be installed for telephone instrument wiring.

Other recommendations formulated as a result of the study include the following:

- The move into the new facility should occur at the same time that a new telephone directory is issued and should be accompanied by a publicity campaign to minimize call delays.
- An individual--other than an operator--should be assigned responsibility for management of the Board's telephone system.

The choice of a voice communications system should take into account the following factors:

- Because common-carrier tariffs are in a state of flux, the economic constraints that now dictate the selection of a CENTREX II system may change in the near future. For example, should the telephone company interconnect tariff be significantly reduced, the purchase of a direct inward-dialing system could become a cost-effective course of action for the Board of Education.

- Sharing of a CENTREX system with the County Government would, in all likelihood, restrict the options available to the Board in the future, since a decision to replace CENTREX with an independent system would have a serious impact on telephone system for the entire County Government.

In recommending the CENTREX system, we therefore suggest that the Board reserve the option of considering in the future another system that may prove more cost-effective.

GLOSSARY OF TERMS

Add-On Conference - Feature allowing a regular call to grow into a conference call without operator assistance.

All Trunks Busy (ATB) - All possible routes a call might take are busy.

Automatic Identified Outward Call - Feature whereby outgoing charge calls are automatically recorded by extension number.

CCS (one hundred - C, Call Seconds) - The number of seconds a line is in use divided by 100. Used to describe traffic loads.

Camp-On - Feature which automatically holds a call until the line becomes free.

Demand Exceeds Capacity (DEC) - The probability that a call will be lost (this differs from the ATB probability).

Direct Inward Dialing (DID) - The ability of a caller to reach a PBX extension directly without operator assistance.

Erlang - A measure of traffic intensity. One Erlang is equivalent to 36 CCS.

Foreign Exchange (FX) - Local telephone service originating at an exchange in another community.

Grade of Service - A measure of system efficiency. Dial-access trunks are normally graded by the probability of an ATB condition, operator-accessed trunks by the average delay before a line is available.

Key Instrument - A telephone terminating more than one line.

Line - A general communications term used in the following senses:

(a) Conductor(s) between a central office and a subscriber

(b) Conductors associated with a particular telephone instrument

(c) Any communications channel between two points

Night Answering - A feature permitting calls to be answered when the PBX is unattended.

Private Branch Exchange (PBX) - A manual exchange connected to the public telephone system on the user's premises and operated by the user.

Power Failure Transfer - Feature which automatically connects pre-assigned extensions to central office trunks when a power failure occurs.

Single Line Instrument - A telephone instrument capable of terminating only one line.

Station Controlled Call Transfer - A feature permitting any extension to transfer an established call to another extension without operator assistance.

Tariff - The published rate for a specific device, facility, or type of service provided by a communications common carrier. Also the medium through which the FCC approves or disapproves such facilities or services. The tariff thus becomes a contract between the customer and common carrier.

Transfer to Alternate When Busy - A feature which automatically reroutes an incoming call when the called station is busy.

Trunks - Lines between two exchanges, as used in this study.

Utilization - The ratio of the time a facility is in use to the total time available.

Wide Area Telephone Service (WATS) - Service allowing a user to make unlimited long-distance calls within a certain region (usually a state or group of states) for a flat monthly rate.

CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 SCOPE

The telephone communications study conducted for the Anne Arundel County Board of Education by ARINC Research Corporation was divided into two phases. Phase I of the study was designed to identify the telephone communications requirements of the Anne Arundel County Board of Education and to identify the telephone services that will be required when the Board of Education combines several existing offices into a single new facility on Riva Road. The possible benefits and disadvantages of sharing a CENTREX II system with several county government offices were also specifically addressed, since the CENTREX offering would be available to the Board under this arrangement. Phase II of the study comprises an evaluation of the telephone requirements of the Anne Arundel County schools.

The purpose of this report is to document the results of the Phase I study. At the conclusion of Phase II, we will provide a final letter report, summarizing school requirements and our recommendations.

1.2 STUDY APPROACH

The determination of the voice communication requirements of the Board of Education facility to be located on Riva Road in Annapolis consisted of five tasks, as follows:

Task 1 - Collect data defining the current telephone communications system for the Board of Education

Task 2 - Analyze the collected data to determine present and future requirements

Task 3 - Define factors to be considered in leasing or buying the telephone system hardware required

Task 4 - Estimate site requirements for the new facility

Task 5 - Prepare a report containing the results of the study with recommendations to the Board of Education

Information regarding the present system was obtained from a number of sources. Data concerning foreign exchange lines, trunks, telephones, extensions, and switchboards were gathered from the Board of Education and the C&P Telephone Company of Maryland. Survey questionnaires were prepared and distributed to switchboard operators and all other Board of Education personnel to assist in determining calling patterns and traffic loads. All long-distance telephone bills from the telephone company for the past school year were examined to determine historical calling patterns and seasonal variations. Various departments under the Board of Education--administrative, data processing, food services, transportation, and purchasing-- were questioned regarding new applications and growth requirements over the next two to three years.

The data collected from the various Board of Education offices were analyzed to determine the traffic load in the new combined facility. Adjustment factors were applied to the data to correct for seasonal variations, growth requirements, and busy-hour loads.

The C&P Telephone Company of Maryland, International Telephone & Telegraph Company, and United Business Communications Company were requested to provide cost estimates for PBX and direct inward-dialing systems based on the anticipated trunk requirements and traffic loads. Information received from these vendors was evaluated to develop preliminary estimates of equipment associated costs, maintenance costs, and tariff rates. The vendors also provided information on environmental, power and floor-space requirements.

1.3 REPORT ORGANIZATION

Chapter Two describes the existing Board of Education telephone facilities and the data collection and analysis effort undertaken to determine the telephone system usage at each facility.

Chapter Three identifies the prospective telephone communications requirements of the Board of Education in the new facility, based on our analysis of the data collected.

Chapter Four discusses the characteristics and costs of systems that could be installed in the new facility to meet the estimated usage requirement.

Chapter Five presents conclusions and recommendations based on the analyses performed.

Four appendixes to this report contain (1) descriptions of the voice communication systems (offered by the telephone company and the independent suppliers), (2) a cost analysis of the competing systems, (3) a description of the survey forms used to collect the telephone traffic data, and (4) a survey of the C&P Telephone Company toll charges for the 1971-1972 school year.

CHAPTER TWO

EXISTING TELEPHONE COMMUNICATIONS SYSTEM

The administrative functions of the Anne Arundel County Board of Education are conducted in five facilities occupying a total of seven buildings. The present telephone communications system serving these facilities is discussed in the following sections.

2.1 CURRENT FACILITIES

The Green Street office and Chinquapin Annex are the only facilities having switchboards. The Chinquapin Annex private branch exchange (PBX) also serves the Snyder and Chesapeake Buildings. Table 1 shows the elements of the current telephone configuration at all five facilities.

Location	No. of Trunks	No. of Extensions	No. of Foreign Exchange (FX) Lines		No. of Wide Area Telecommunications Service (WATS) Lines
			Balt.	Wash.	
Green Street	14	67	2		1
Chinquapin Annex	20	97	2	1	
Pasadena	4	6			
Arnold	10	22			
Millersville	4	7			

Table 1

Board of Education Telephone Facilities

Location	Number of Instruments	Number of Respondants	Number of Calls within Building	Number of Calls to Other Board Offices	Number of Other Local Calls	Number of Long Distance Calls	Total Number of Calls
Green Street	82	71	810	485	1039	204	2538
Chinquapin Annex	111	92	464	373	2216	307	3360
Snyder Building	9	11	45	148	263	44	500
Chesapeake Bldg.	4	2	14	6	29	12	61
Arnold	34	32	77	247	1166	34	1524
Pasadena	18	14	30	73	322	13	438
Total	258	222	1440	1332	5035	614	8421

Table 2

SUMMARY OF 5 DAY TELEPHONE SURVEY

Five additional FX lines are used between the Green Street facility and the Annex. Long distance calls are usually dialed directly or, when appropriate, placed via WATS, which can also be accessed by the Annex through the Green Street PBX. Both PBXs have a single position, normally manned full-time from 8 a.m. to 4:30 p.m., five days a week.

2.2 TELEPHONE SYSTEM USAGE

A survey form--the Outgoing Telephone Call Recording Form--was distributed to each telephone extension to determine calling patterns in the present system. A reproduction of the form is contained in Appendix C. These forms were to be completed by anyone calling from any extension during the five-day period from 30 October through 3 November, 1972. The collected forms were analyzed to determine the number of calls placed to (1) extensions in the same building, (2) other Board of Education offices, (3) local destinations, and (4) long-distance destinations. Table 2 summarizes data compiled from the Outgoing Telephone Call Recording form.

Incoming telephone calls during the same period were recorded by the switchboard operators. They also recorded the number of times the FX lines were used, the number of WATS calls, and the duration of outgoing calls on the FX and WATS lines. Table 3 summarizes the data obtained from the operator logs relating to incoming calls and usage of the FX and WATS lines.

Location	No. of Incoming Calls	No. of Outgoing Calls			Total Outgoing Calls (Duration in minutes)
		Balt.	Wash.	WATS	
Green Street	2760	106		57	347*
Annex	2972	236	114	-	1380

Table 3

Five-Day Survey of Incoming Calls and FX Line Usage

The logs completed by the switchboard operators at the Green Street facility were used to develop a histogram, shown in Figure 1, depicting the hourly fluctuations in incoming traffic volume. The figure shows that over 44% of the calls occur between 9 a.m. and 12 noon. The largest traffic peak observed during the five-day survey occurred in the "busy hour" of 10 a.m. to 11 a.m.; the single greatest peak observed during this busy hour was 17.5% of the total incoming calls for that day. This value was used to compute the highest expected daily peak. Average call duration was based on the duration of all calls placed via the Washington and

*Does not include WATS calls because these might not be representative of Board telephone traffic.

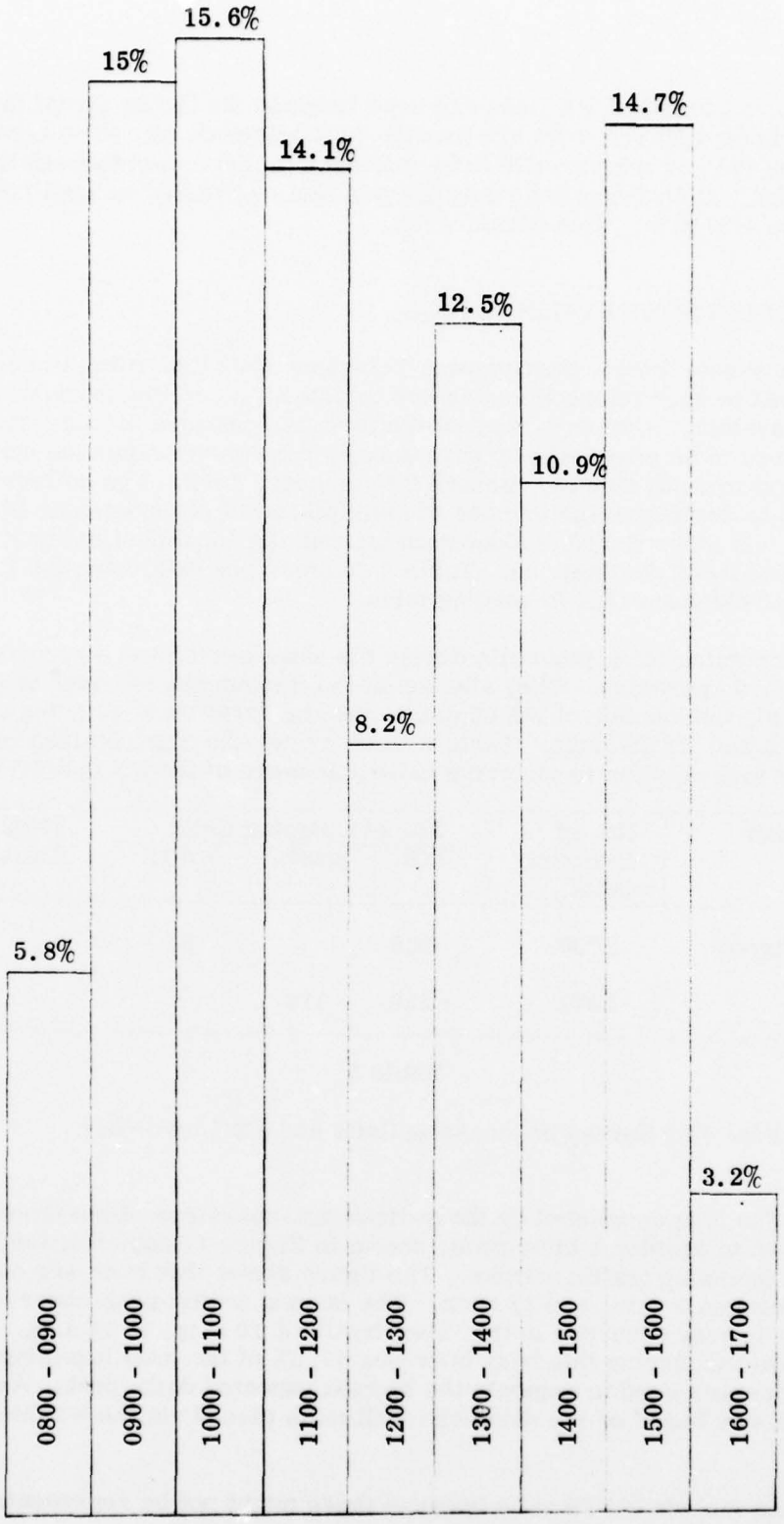


FIGURE 1 DISTRIBUTION OF GREEN STREET INCOMING CALLS BY HOUR
(BASED ON 5-DAY SURVEY)

Baltimore FX lines during the survey. Line usage was determined by multiplying the average call duration by the number of calls made during the survey period. In this report, line usage is expressed in CCS units, CCS being the symbol for 100 (represented by "C") call-seconds (CS).

All telephone company long-distance billings to the Board of Education facilities for the previous school year were examined for monthly and seasonal variations in traffic volumes as well as growth patterns. These data are presented in Appendix D. The month-to-month variations can be seen in Table 4, which presents each month's billing as a normalized percentage of the billing for the highest month. Usage is directly related to the monthly bill, since the rates are based on the first three minutes of use and an added charge for each additional minute.

Based on a detailed analysis of several months' billings, the cost per long-distance call was found to be a reliable method of estimating the total number of calls from the amount billed.

The values in Table 4 were used as a direct index of monthly telephone system usage for the Board of Education. Peak yearly usage was determined, based on the ratio of the cost index for the peak month to the cost index for the month of the survey.

From Table 4, it can be seen that the line usage for various facilities peaks at different times during the year; also, that for a combined facility (see total weighted average column) the usage tends to fluctuate somewhat less.

The total-weighted-average data for each month illustrates that the billing period during which the survey was conducted (19 October to 18 November) should provide less than peak-usage statistics. Subsequent adjustement of the usage data was necessary to account for the monthly variations in system load.

Daily variations in system load can result from personnel absences, Board meetings and school holidays. In addition, certain offices, such as the Transportation Division, have unusual variations in traffic volumes due to the opening of schools, inclement weather, and emergency school closings. The Personnel Department experiences seasonal variations because of interviewing and hiring of applicants for positions within the county schools and Board of Education.

To adjust for possible differences between the actual usage rate during the one-week study period and the usage rate during the entire one-month billing period, all bills for the period encompassing the study (19 October through 18 November 1972) were checked against the total amount billed and a study adjustment factor calculated as follows:

TABLE 4

MONTHLY VARIATIONS IN BOARD OF EDUCATION LONG-DISTANCE BILLINGS, 1971-1972
Normalized for Highest Month at Each Facility

Month *	Green St.	Annex	Arnold**	Pasadena**	Total Weighted Average***
19 Aug – 18 Sep	0.944	0.594	0.767	0.647	0.931
19 Sep – 18 Oct	0.733	0.372	0.841	0.800	0.717
19 Oct – 18 Nov	0.593	0.522	0.524	0.900	0.705
19 Nov – 18 Dec	0.564	0.404	0.676	0.692	0.626
19 Dec – 18 Jan	0.536	0.336	0.711	0.537	0.568
19 Jan – 18 Feb	0.825	0.529	1.000	0.899	0.875
19 Feb – 18 Mar	0.819	0.517	0.866	1.000	0.858
19 Mar – 18 Apr	0.587	0.513	0.725	0.824	0.713
19 Apr – 18 May	0.655	0.631	0.602	0.437	0.776
19 May – 18 Jun	0.657	1.000	0.728	0.468	1.000
19 Jun – 18 Jul	0.785	0.650	0.553	0.399	0.845
19 Jul – 18 Aug	1.000	0.491	0.608	0.356	0.866
Avg.	0.725	0.546	0.717	0.662	0.790

*Based on 22 working days per month per month.

**The billing period for these facilities does not coincide exactly with the others.

***The total weighted average is calculated from the combined bills for each month.

$$\text{Study Adjustment Factor} = \frac{\text{Number of long-distance calls during the billing period}}{\text{Number of long-distance calls during the survey period}} \times \frac{\text{Number of days in the survey period}}{\text{Number of working days in the billing period}}$$

$$= \frac{(642) \cdot (5)}{(164) \cdot (22)}$$

$$= 0.89$$

This factor is used in Chapter 3.1 to determine the forecast peak usage for the new facility.

2.3 ASSUMPTIONS

The estimation of telephone usage was predicated upon certain assumptions and circumstances. These were:

- We assumed that the holding time of outgoing FX calls was representative of the holding times for all calls.
- We assumed that the ratio of long distance calls to the total number of calls for any given month (incoming, outgoing, and internal) would be approximately constant. Thus, the long-distance billing data could be used to estimate usage for the entire system.
- The billing period for Pasadena and Arnold did not coincide with that for Green Street and the Annex. Since Pasadena and Arnold account for only about 13% of the total bill, we assumed that the amount billed for the nearest overlapping period could be used directly without significantly affecting the results.
- The Millersville facility will not be combined with the others in the new building; accordingly, data from this facility were not employed in the usage calculation.

CHAPTER THREE

FUTURE TELEPHONE COMMUNICATIONS REQUIREMENTS

Future telephone communications requirements are based on present system usage and predictable system changes. In this chapter, we will project the new facility trunk requirements for the peak traffic volume expected during the first year of occupancy. Given these trunk requirements, it will be possible to select the best size system for the Board of Education with sufficient flexibility to absorb traffic increases over the next ten years.

3.1 FACTORS INFLUENCING TRUNK REQUIREMENTS

The data obtained during the survey period represent a limited measurement in a continuously changing environment. Some of the factors affecting this measurement and the adjustments made to compensate for these factors are described in the following paragraphs.

(1) Historical Calling Patterns - Seasonal variations in the volume of telephone calls were described briefly in Chapter Two. If long-distance calls are considered representative of the overall incoming and outgoing traffic during a specified period, Table 4 may be used to determine the monthly adjustment factor. Normal practices dictate that a communications system be designed for peak traffic loads to enable it to cope with the highest expected volume without severe degradation of service. If this philosophy is applied to the expected monthly variations in long-distance calls, an adjustment factor for the study period may be calculated from the ratio of the peak-month index (May-June) and the index for the month encompassing the study period (October-November):

$$\text{Monthly Factor} = M = \frac{\text{Peak-month traffic volume index}}{\text{Study period traffic volume index}}$$

$$= \frac{1.000}{0.705}$$

$$M = 1.418$$

(2) Growth - Any new system should provide adequate growth capability to meet normal yearly increases in volume. The growth in telephone traffic for Green Street and the Annex during the billing periods of 19 August to 18 September and 19 October to 18 November of 1972 as compared to the same periods in 1971 was approximately 2.9%; the increase in personnel during the past year was 3.9% (358 to 372 people). A conservative estimate of 4 percent was applied to the traffic data in order to estimate increased telephone usage by the time the Board moves into the new facility.

The forecasted increase in Board of Education personnel over the next ten years (through 1982) is 17.4 percent*, thus the system should be able to accommodate at least 17 percent increase in usage without affecting service. This will be considered in Chapter Four when selecting a system.

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* Data on current and future personnel staffing was furnished by the Board of Education for use in this study.

(3) New Applications - New applications of the voice communications system will consist primarily of lines for time-sharing operations. The Board's Data Processing Department estimates that two dozen Cathode Ray Tubes (CRT's) will be installed in the new building for local data-entry and retrieval. However, these devices are normally connected by special cables and would not require telephone lines.

In addition to local peripheral devices, remote terminals are envisioned for installation in each secondary school using dial-up connections. Direct in-dial lines should be provided for this purpose and may be added at any time with negligible effect on the results of the present study. Therefore, the factor applied to the traffic data reflecting new applications is unity.

(4) Stimulation - Any new system can be expected to stimulate a certain amount of additional usage because its users will demand more of the increased capability. Based on discussions with telephone company traffic-engineering personnel, a one time adjustment factor of two percent was used to approximate increased usage from stimulation in the new facility.

(5) Centralization - Combining the separate Board of Education facilities into a single building may eliminate some telephone communications equipment because of the proximity of offices and personnel. The impact of this reduction would be primarily on internal calls and would therefore have little effect on the number of trunks required. The number of links, or possible simultaneous internal calls, however, should be somewhat less than present usage indicates. In this study, a value was not assigned to this factor, since it would be offset to some degree by additional calls that would be made if conveniences offered with a new system were available now.

The net effect of seasonal variations, growth, new applications, and stimulation is the product of these factors:

$$F = 1.42 \times 1.04 \times 1.00 \times 1.02$$

$$= 1.51$$

or a 51% increase over the present traffic volume

3.2 NEW FACILITY TRAFFIC LOAD ESTIMATES

The F factor, the study adjustment factor (0.89), and the peak-hour factor (17.5%) were applied to the survey data to determine the greatest traffic load that should be expected in the first year during any hour of the busiest month at the new facility.

Usage in CCS for the present facilities (see Table 5) was calculated from the total number of calls for the various types of traffic. A busy-hour usage factor based on average holding time per call and the peak-hour volume was calculated as follows:

$$\text{Busy Hour Usage Factor} = (\text{Percent daily volume/busy hour})(\text{minute/call})(\text{CCS/minute})$$
$$= (.175)(3.78)^{*}(0.6)$$
$$= 0.397 \text{ CCS/call/busy hour}$$

This factor represents the multiplier of the one-day total call volume, expressed in calls per day, as shown in Table 5, necessary to arrive at the usage in CCS units per busy hour.

The forecast usage for the first year in the new facility (see Table 5) was estimated from the study adjustement and monthly factor as follows:

$$\text{Forecast Peak Usage} = (0.89) \cdot (1.51) \cdot (\text{present usage})$$
$$= 1.34 \cdot (\text{present usage})$$

3.3 NEW FACILITY TRUNK REQUIREMENTS

Once the communications load was established, it was possible to estimate the number of trunks required to obtain a given grade of service. The criteria used to grade dial-access trunks is based on the probability of finding all trunks busy; for example, a PO1 grade of service indicates a probability of the user finding the lines busy once in 100 times during the busy hour. For P10 service, 90 calls in 100 will find an idle line on the first attempt; the remaining 10 calls will encounter or create an all trunks busy condition.

In the design of operator access trunks, the grade of service is specified in terms of the average delay before a line is available and is expressed as a multiple of the holding time (the length of time a line is in use, including coordinating time, operating time, and conversation time).

Queuing theory was used to evaluate trunk requirements once the grade of service and traffic load had been determined. Tables based on exponential holding times and random arrival of calls were used to determine the probability of all trunks being busy. The actual formula is somewhat more difficult to use, taking the form:

*This time is calculated from Table 3, based on FX line usage, and a sample size of 456 calls.

TABLE 5

NEW-FACILITY TRAFFIC VOLUME ESTIMATES

Type of Traffic	5-Day Total Volume (No. of Calls)	1-Day Ave. Volume (No. of calls)	Busy-Hour Usage (CCS)	Forecast Peak Usage (34% increase)
Internal Calls	2772	554.4	220	295
Incoming Calls	7357	1471.0	584	783
Outgoing "9" Level	5035	1007.0	400	536
Outgoing L.D.	614	122.8	49	66
Baltimore FX	342	68.4	27	36
Washington FX	114	22.4	9	12
WATS	57	11.4	5	7

Busy Hour = 17.5% of Daily Total

Holding Time = 3.78 minutes (average)

Each minute of use is equivalent to 0.6 CCS.

$$P_B = 1 - \left\{ \frac{\sum_{n=0}^{M-1} \frac{(R)^n}{n!}}{\sum_{n=0}^{M} \frac{(R)^n}{n!}} \right\} \Bigg/ \left\{ 1 - p \left[\frac{\sum_{n=0}^{M-1} \frac{(R)^n}{n!}}{\sum_{n=0}^{M} \frac{(R)^n}{n!}} \right] \right\}$$

where R is the traffic intensity in Erlangs, and M is the number of trunks, and p is system utilization.

An expression termed the Khintchine and Polloczek formula was used to evaluate delay times for operator access trunks. This equation assumes that no callers leave the queue, that service times are exponentially distributed, and that calls assume an arrival pattern of the Poisson (random) form:

$$\text{Mean Waiting Time} = \frac{P_B}{M} \times \frac{S}{(1-p)}$$

where p is the average trunk utilization, S is the mean holding time, M is the number of available trunks, and P_B is the probability that all trunks are busy, as shown above. The actual value of P_B may be calculated from the formula

Type of Traffic	Forecast Peak Hour Traffic CCS	No. of Trunks Required								Recommended Number of Trunks
		All Trunks Busy			Delay (Seconds)			Demand Exceeds Capacity		
		P=0.10	P=0.05	P=0.02	1 Line	2 Lines	3 Lines	P=0.05	P=0.01	
Incoming	783	28	30	32	-	-	-	27	32	32
Outgoing	602	23	24	26	-	-	-	22	26	22
Incoming* Plus Outgoing	1385	47	49	52	-	-	-	44	51	47
Balt. FX	36	3	3	4	∞	76	10	-	-	3
Wash. FX	12	2	2	3	114	7	0	-	-	2
WATS (Area 3)	7	1	2	2	55	3	0	-	-	2

* If two way lines are used as in Centrex II or other direct inward dial systems, some savings results in the total trunk requirement.

TABLE 6

TRUNKS REQUIRED FOR VARIOUS GRADES OF SERVICE DURING THE BUSY HOUR

or may be found in tables, such as those in Martin.[1]

Studies by ARINC Research Corporation[2] have shown that a potentially more significant measure of service than "all trunks busy" is the probability that demand exceeds capacity (DEC). This is the probability that at a given time there will be more users for the system than the system can accommodate. The ideal situation is one where all trunks are busy and demand never exceeds capacity. In practice, however, the user is concerned primarily with the number of calls that will be blocked or lost rather than the probability that all lines are in use. Using the "demand exceeds capacity" criterion to determine trunk requirements therefore results in the desired grade of service, although trunk utilization is increased from that which would occur if the "all trunks busy" grade of service criterion were used. In short, the "demand exceeds capacity" criterion usually results in fewer trunks for the grade of service desired than would the "all trunks busy" criterion.

The probability that demand will exceed capacity can be calculated as one minus the summed Poisson probabilities that zero through M users will need the system at the same time where M is the number of trunks. The actual expression used to evaluate the Board's trunk requirement is:

$$P = \frac{\frac{(R)^M}{M!}}{\sum_{n=0}^{M} \frac{(R)^n}{n!}}$$

where R is the traffic intensity in Erlangs and M is the number of available trunks. It is assumed that all lines are equally loaded and that no queues are formed.

Table 6 shows the trunk requirements for various grades of service during the anticipated peak-hour load in the new facility. Service would improve as the load decreased with a given number of trunks. The number of trunks recommended is based on a 0.01 probability that the demand will exceed capacity for one incoming call in a hundred during the busy hour. In the interest of economy, a somewhat greater tolerance was allowed for outgoing calls with demand exceeding capacity on 1 call in 20. Foreign Exchange and WATS line recommendations are a compromise between acceptable delay time and circuit cost. While it is desirable to keep circuit utilization as high as possible for maximum return on money invested in trunks, lower utilization was chosen because of the excessive delay that could be encountered with fewer trunks. If these lines were accessed manually through an operator and some additional delay was acceptable, the trunk requirement could be reduced.

1 Martin, James, "Systems Analysis for Data Transmission," Prentice-Hall, Inc. Englewood Cliffs, New Jersey, pp. 858-860.

2 Retterer, B. "Proposal for Development of Advanced Telephone Trunk Criteria," ARINC Research Corporation, 1972.

After line requirements shown in Table 6 were established, three independent vendors were asked to estimate the costs for the systems they would recommend to satisfy these requirements. Chapter Four discusses the various systems proposed in terms of cost and features.

CHAPTER FOUR

SELECTION OF A TELEPHONE SYSTEM

The trade-offs between leasing the required telephone system from the telephone company or buying it from an outside vendor involve several factors. One of the most obvious is the cost of each system; others--less obvious--include system-support requirements such as maintenance and management. This chapter defines each factor and describes its relative importance. In the comparison of alternative systems, typical or estimated probable costs were used for each factor to allow a total cost comparison of the various systems.

The factors considered for each system were grouped into three general categories:

(1) Basic PBX Features

(2) Equipment Costs (purchase or lease)

(3) System Support

The factors considered in categories 1 and 2,above, will be defined as they are applied to each of several systems compared in section 4.2. The factors considered in category 3 are defined and discussed in the following paragraphs.

4.1 SYSTEM SUPPORT

Basic questions to be answered concerning system support are listed in sections 4.1.1 through 4.1.4. Section 4.1.5 discusses the proposed systems in light of these questions.

4.1.1 MAINTENANCE SUPPORT

(1) What will system maintenance cost and who will provide it?

(2) How fast can service personnel respond to requests for changes or solution of equipment problems?

(3) Will the vendor assume overall responsibility for coordinating repairs with the serving telephone company, or will the customer be faced with the task of solving his own jurisdictional maintenance problems?

(4) What will service charges, such as additions, deletions, and changes, cost?

4.1.2 MANAGEMENT SUPPORT

(1) Who will determine the need for and supervise system changes, such as deletions, additions, and rearrangements?

(2) If a major change in equipment or method of operation is suggested or planned, who will evaluate or coordinate the change?

(3) Who will accomplish cost allocation and resolve account information or service-charge discrepancies?

4.1.3 LIABILITY

(1) If the equipment is damaged by fire or otherwise, who will bear the cost of repair or replacement?

(2) Who will assume the cost of insuring the equipment?

(3) Will the purchased equipment be exempt from personal property taxes?

4.1.4 PERFORMANCE AND TRAINING

(1) Are performance guarantees adequate?

(2) Does the performing warranty cover the entire system or just certain key components?

(3) Will training in the operation of the system (both recurrent and initial) be provided and what will it cost?

(4) Will communications consulting be provided by the vendor and at what additional cost, if any?

4.1.5 DISCUSSION

Based on information obtained from the telephone company and the two independent suppliers, few significant differences exist in the quality or cost of system support.

One such difference is in maintenance costs. For privately owned systems, these costs are a significant factor that must be considered in the selection process; the telephone company does not charge for maintenance. Service charges for additions, deletions or modifications to the system are comparable among the three suppliers. Response time on service calls is also comparable since none of the suppliers contacted is located further than the Washington metropolitan area. Appendix B shows the cost for various customer-owned-equipment maintenance contracts.

The Board of Education should be primarily responsible for management support and should not leave this responsibility to the telephone company or an equipment supplier. Each vendor appears to be able to respond to usual management requirements.

Personal property taxes would apply only to privately owned systems, however, such systems would also be eligible for an investment tax credit. Neither of these considerations is applicable to the Board, a Government organization.

Facility losses are the user's responsibility in the case of privately owned systems. Performance guarantees for all of the systems are equivalent in that system performance specifications will be met by the supplier. All suppliers indicated that any necessary training and consultant services will be provided free of charge on a continuing basis.

4.2 COMPARISON OF AVAILABLE TYPES OF VOICE COMMUNICATIONS SYSTEMS

This section will compare the basic PBX features afforded and the total equipment and support costs of the following systems, all of which have been examined for the purposes of this report:

1. Bell System CENTREX II, shared with the Anne Arundel County Government

2. Bell System 770-type PBX

3. Model FXB-304U1 (CENTREX type) system, supplied by United Business Communications (UBC)

4. Model TE400A EPABX, supplied by ITT - Communication Equipment Division

All cost comparisons were made on the basis of ARINC Research estimates and cost figures supplied by the C&P Telephone Company of Maryland and the two independent manufacturers. In the case of the CENTREX II service, only the system that would be shared with the County Government was considered, since an individual CENTREX system for the Board of Education would be prohibitively expensive because of the tariff.

4.2.1 BELL SYSTEM CENTREX II (shared system)

The CENTREX II system affords several significant features not available in the present Bell System 701-type PBX used by the Board of Education. They are:

(1) Direct Inward Dialing: All incoming calls are dialed directly with 7-digit numbers, without operator intervention.

(2) Automatic Identified Outward Calls: At the Board's discretion, all outgoing calls could be dialed directly and a separate statement of toll charges for each station could be furnished monthly by the telephone company.

(3) Significant Reduction in Operators: The Board of Education, in its new facility, would require 0.4 operators on an allocated basis as part of the shared system, whereas, for its own system, 2.5 operators would be required. The shared CENTREX represents a reduction in operator requirements (one operator versus two or three).

(4) Best Grade of Service: C&P would assume full responsibility and absorb all costs in engineering a grade of service comparable to the long-distance network. This grade of service is considerably better than that found in most PBX systems.

As estimated by C&P Telephone Company of Maryland, the cost of the CENTREX II service, exclusive of operators and consoles, would be $3,215 per month for a system with 225 main stations. This sum would be the Board's allocated portion of the total County bill of $14,221 per month for a total of 1,054 stations (exclusive of operators, consoles, etc.).

The CENTREX II rate tariff provides a rate break point at 900 stations and above. Should the Board of Education not participate in the shared service, the County system would be reduced from 1,054 to 829 stations (a decrease of 225). This would increase the County Government's cost by about 4%, or approximately $500 per month, should they decide to pursue the shared offer without the Board's participation.

To determine what problems might be expected with a CENTREX system, the Baltimore County Board of Education was consulted, since they are similar in function, size, and telephone requirements* to the Anne Arundel County Board of Education. In addition, their CENTREX is shared with the Baltimore County Government. The Baltimore Board was able to eliminate all operators (two full time plus two relief) by placing an information number in their transportation department. The CENTREX responds much more quickly than the manual PBX to incoming calls and better serves the Board's needs. The grade of service provided was described as excellent. The telephone company has also been very responsive to trouble calls and requests for changes.

4.2.2 BELL SYSTEM 770-Type PBX

The 770-type PBX system has several advantages and disadvantages when compared with the shared CENTREX II offering:

(1) The cost of this system, using 225 main stations, is $2,654 per month, compared to $3,215 per month for the CENTREX. The savings would be $561 per month.

(2) The space required for this system is 25 x 30 square feet, rather than the 25 x 50 square feet required for the shared CENTREX--a space reduction of about one-half.

(3) Direct inward-dialing and automatically identified outward dialing are not available. An operator must handle every incoming call and extensions cannot be billed directly.

(4) Telephone company studies show that 2.5 operators would be required for this system, as compared to 0.4 for the shared CENTREX II system. In practice, the Board would probably require two full-time operators and one relief operator. The loaded monthly rate for operators (salary plus benefits) is approximately $591 per month.** The net effect of the $561-per-month saving in system costs and the increased operator requirement is an increase of $621 per month (2 x $591 - $561) for the 770 system over the shared CENTREX II offering. If the relief operator is a secretary or clerk, cross trained to operate the switchboard, the monthly savings are only $30.

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* Mr. M. Cole, Associate Supervisor of Business and Finance for the Baltimore County Board of Education, was contacted. The original PBX system served approximately 375 people via 275 telephones with 17 trunks.

** Figures furnished by the Board of Education for the present PBX system.

Assuming that total system cost (operation and equipment) is the major determinant and that space requirements and call features are lesser considerations, the CENTREX II system appears to be much more desirable or slightly more desirable, depending on how the Board is able to supply a third operator.

On the basis of information provided by C&P Telephone Company, we estimated that one-time initial installation costs of the CENTREX II service would be approximately $8,800. C&P Telephone was unable to validate this figure, since they had not developed it, but they agreed that it seemed to be approximately correct. Actual installation cost would depend on the amount of key equipment used in the new facility.

4.2.3 MODEL FXB-304U1 SYSTEM SUPPLIED BY UNITED BUSINESS COMMUNICATIONS

(1) The system supplied by United Business Communications offers service closely comparable with the Bell System CENTREX. Direct in-dialing is provided; however, automatically identified outward dialing is not provided. The absence of the latter feature means that outgoing toll calls are not automatically identified on a per-station basis.

(2) This system uses a crossbar-type switch which is much more compact than the CENTREX II service. Space requirements would be reduced to about 12% of the 1250 square feet required for CENTREX, or 150 square feet.

(3) The major problem with the UBC system appears to be its traffic-handling capability. Traffic studies of the Board of Education conducted by ARINC Research showed rather heavy busy-hour traffic loads. The capability figures provided by the manufacturer indicate that this system would operate very close to its maximum capacity, with little or no reserve for unexpected traffic growth or high-peak periods.

Total purchase price of the UBC system, with approximately the same features and equipment as in the CENTREX II and including installation, is $87,250. The first year's maintenance is included in the purchase price and each year thereafter maintenance would cost $2400, with the option to pay a flat labor and part charge if this should prove more economical for the Board of Education. All support costs other than maintenance are included in the purchase price.

The monthly charge by the telephone company for central office trunks and interconnection devices would be about $2,588 per month. This cost would be in addition to the total purchase price and maintenance charges paid to the manufacturer.

4.2.4 ITT MODEL TE400A EPABX

(1) The system offered by ITT provides essentially the same type of service as the UBC system described in section 4.2.3. This is perhaps the most sophisticated system offered in that it is fully electronic, with no moving switch parts.

(2) Space requirements would be much the same as for the UBC system, or 120 square feet.

The purchase cost of the ITT system, including the first year's maintenance, is about $145,000. After the first year, maintenance is charged on either a flat labor rate plus parts or on a fixed-price contract. This system would also entail monthly charges from the telephone company of about $2,588 per month for trunks and interconnect devices.

4.3 COST COMPARISON

Table 7 contains the basic data used in the cost comparison of alternative systems. Figure 4-1, developed from these data, depicts the year-by-year cost comparison of the three candidate systems previously discussed that allow direct inward-dialing. The comparison indicates that, on a cost basis, the CENTREX II system is the most attractive. The figure also shows that if the interconnect and DID-station numbering charges were to be eliminated in the near future, the ITT and UBC systems would become comparable in total cumulative costs to the CENTREX II system. In this analysis, we have assumed that the salvage value of the privately owned systems would be zero after ten years and no value was attached to floor space. Several major features of the three direct inward-dialing systems are compared in Table 8.

A similar comparison of the three systems without a direct inward dialing capability (see Appendix B for details) showed that the monthly cost of each system was increased by the additional operator requirements. Both vendor systems were more expensive than the Bell System 770-type PBX because of recurring telephone trunk and interconnect device charges.

An important factor bearing on this study and meriting repetition is the possibility that telephone company tariffs may be revised in the future to reduce interconnect-device and DID-station numbering costs. Since the interconnect-device charges account for 9 % to 10% of the monthly recurring charges and station number charges (when required) account for 13% to 15% significant savings could result from a tariff reduction. Should a substantial reduction occur, the Board could consider replacing the existing telephone equipment with a privately owned system.

TABLE 7

DATA USED IN COST COMPARISON OF ALTERNATIVE SYSTEMS

Cost Factors	System		
	CENTREX II	ITT (EPABX TE400A)	UBC (FXB-304U1)
Installation (one-time)	$8,800	$1,150	$1,150
Purchase Price (Cash)	Not Applicable	145,000	87,250
Purchase Price (monthly total financed charges)	Not Applicable	1,689	1,239
Monthly Line Charges*	None	1,510	1,510
Monthly Interconnect Charges*	None	400	400
Monthly DID Station Charges*	None	580	580
Monthly Lease Charges*	3,036**	Not Applicable	Not Applicable
Monthly Maintenance Charges*	None	181	208
Total Monthly Charges	3,036	9,360	3,937

* A 3% yearly rate of growth has been assumed for these cost factors. A federal tax of 10% has been included for all these cost factors except the monthly maintenance charges.

**CENTREX II costs were pro-rated equitably among the users for purposes of this cost comparison. The telephone company estimate of $3,215 assumes the Board is billed as the primary location.

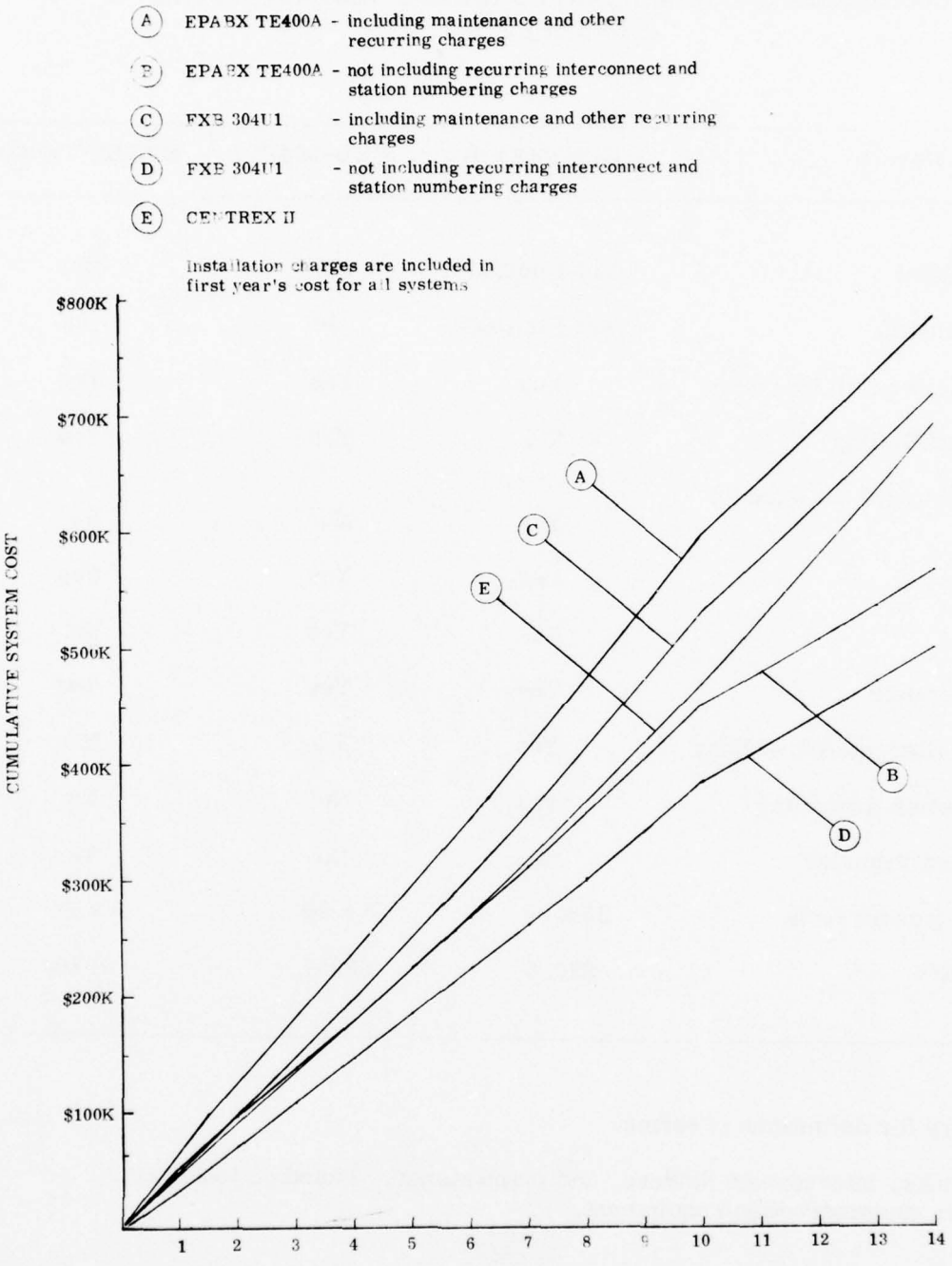

FIGURE 4-1

TOTAL CUMULATIVE COSTS FOR THREE SYSTEMS
(AMORTIZED OVER 10 YEARS)

TABLE 8

COMPARISON OF MAJOR DIRECT INWARD-DIALING SYSTEM FEATURES

Feature *	CENTREX II	FXB-304U1	EPABX TE400A
Lines (maximum)	Not Limited	700	400
Trunks (maximum)	Not Limited	50	96
Station Controlled Call Transfer	Yes	Yes	Yes
Directo Inward Dialing	Yes	Yes	Yes
Automatic Identified Outward Call	Yes	No	No
Night Answering	Yes	Yes	Yes
Camp On	No	Yes	No
Add On Conference	Yes	Yes	Yes
Transfer to Alternate When Busy	Yes	Yes	Yes
Traffic Statistics Recording	Yes	No	No
Power Failure Transfer	No	No	Yes
Floor Space (square feet)	25 x 50	8 x 19	8 x 15
Monthly Cost**	$3036	$3937	$4360

* See Glossary for definitions of terms.

**Includes trunks, interconnect devices, and maintenance. Based on ten-year financing for customer-owned equipment.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 EVALUATION AND COMPARISON

The cost and capabilities of customer-owned and customer-maintained equipments versus leased PBX and direct inward-dialing equipments were evaluated for three independent suppliers. PBX systems, which are similar in cost to CENTREX II, were eliminated from consideration because they require additional operators and lack certain features offered by the DID systems. Of the three direct inward-dialing systems evaluated, CENTREX II, offered by the C&P Telephone Company of Maryland, was selected. The other two vendors were eliminated for the following reasons:

- United Business Communications (FXB-304U1). Even when purchase cost is amortized over a ten-year period and cumulative costs are considered over a fifteen-year period, this system is more expensive than the CENTREX II, primarily because of the telephone company's monthly recurring charges for trunks and interconnect devices. Further, it is our opinion that this system would often be operating near peak capacity with no trunk-expansion capability.

- International Telephone and Telegraph (EPABX TE400A). This system, with cost amortized over a ten-year period, is more expensive than either competitor because of higher system cost and recurring monthly charges for trunks and interconnect devices. In spite of the greater cost, this system is considered better than the FXB-304U1 because of its greater capacity, expandability, and solid-state design.

Maintenance costs for the two customer-owned systems were included in the cost comparison; both fixed-price and time-and-materials contracts are available from either supplier. Service quality and response time can generally be expected to match those of the telephone company. While maintenance might cost the Board of Education somewhat more over the amortization period with a privately owned system, internal moves and system changes would cost about the same for all three systems. One exception is equipment removal by the telephone company, for which the customer is no longer charged.

The CENTREX II system would not only be less expensive for the Board of Education but would permit a saving of almost $500 a month (or $6000 a year) if established as a shared system for the Anne Arundel County Government and the Board of Education.

The direct inward-dialing systems do not require an operator as such; however, an information number should be provided at the receptionist's desk for directory assistance. The Board may also want to provide an additional information number during the initial switch-over of the new system. Wrong numbers are easily transferred from any phone without operator assistance. Through this feature, callers may be quickly acquainted with the new numbers without having to redial. WATS lines and tie lines can also be used with CENTREX-type systems without operator assistance. Dial levels are provided to enable the user to dial out directly on these lines. Direct inward-dialing systems can also be provided with Foreign Exchange and inward WATS service.

On the basis of information obtained during the survey, little growth is expected in the new system for the immediate future. Requirements for additional trunks or instruments can be easily accommodated on any of the systems discussed except the FXB-304U1, which would probably be operating near capacity.

5.2 SYSTEM SELECTION

ARINC Research believes that the system which most fully meets the long-term needs of the Anne Arundel County Board of Education is one providing direct inward-dialing, or CENTREX-type service. Our reasons for this opinion are:

(1) The operator requirement is reduced from two or three operators to one operator who is generally free to perform other duties, such as those of a receptionist. The saving in operator costs more than offsets the lower lease cost of a PBX system requiring three operators. The costs are approximately equal where two operators are employed.

(2) Direct inward dialing provides improved service over present PBX operation from the user's viewpoint, since inward calls are completed much more quickly, especially during busy periods.

The system recommended for the Board of Education is the Bell System shared CENTREX II as proposed by C&P Telephone Company. This system is considered preferable to the available vendor systems offering direct inward-dialing for the following reasons:

- CENTREX II is the most cost effective system.
- Only CENTREX II can provide automatic identified outward dialing.

- Anne Arundel County telephone system costs will be reduced by approximately $500 per month if the Board participates in the shared offering.

- C&P Telephone Company assumes full responsibility for trunk and switch engineering, and its costs, in the CENTREX II system. The user of a private system is responsible for his own engineering and bears the cost of any changes.

Consultation with the Baltimore County Board of Education, which is similar to the Anne Arundel County Board of Education in telephone requirements, indicates a high degree of satisfaction with CENTREX II.

5.3 SITE REQUIREMENT

A 1250 square-foot (25' x 50') room is needed for the recommended CENTREX II system. The room should be dust-free, with asphalt tile or an equivalent covering on a concrete floor. A 15- or 20-ampere circuit for 110 volts, single-phase AC operation must be provided for primary power. Environmental controls should maintain temperature in the range from 65° to 100°F and limit the maximum relative humidity to 75%.

The C&P Telephone Company should be contacted to determine the door size required for the equipment, lighting requirements, and type of ducting or conduit to be installed for telephone instrument wiring.

5.4 RECOMMENDATIONS

ARINC Research Corporation recommends that the Anne Arundel County Board of Education share with the County Government a CENTREX II system provided by the Maryland C&P Telephone Company. Cost is the major determinant in this recommendation.

We further recommend the move into a new facility occur at the same time that a new telephone directory is issued. A publicity campaign should be coordinated with C&P Telephone to educate the calling public through news releases, post cards, pamphlets listing most frequently called numbers, and other media.

An individual other than an operator, accountable directly to the Board of Education, should be given responsibility for managing the Board's telephone facilities--whether independent or shared--including coordination with C&P Telephone of all number changes, the installation or removal of instruments

and lines, personnel moves, and service problems. This individual would also serve as the focal point for telephone traffic surveys and recommend appropriate system changes to keep telephone service at an optimum level. If a shared system is established, the County Government may appoint a system manager with overall accountability. The Board should nevertheless assure itself that the system manager will be responsive to the Board's telephone requirements.

Future Contingencies

ARINC Research Corporation recommends that the installation of a shared CENTREX II system be implemented in the closest possible coordination with the move to the Riva Road facility and issuance of the new telephone directory. Concurrently, we urge that the Board of Education keep abreast of possible developments that may affect its future course of action respecting telephone service.

We point out particularly that tariffs are continually changing and the economic constraints that make CENTREX II a logical choice at this time may not always be applicable. The Board should recognize that, since it will serve as the primary CENTREX location, any future decision to replace CENTREX with private equipment could seriously affect the entire County telephone system. Choosing CENTREX could tend to restrict the Board of Education and the Anne Arundel County Government to telephone company offerings.

In the event of future tariff changes, a study might be undertaken to determine the feasibility and economy of replacing the entire County system with privately owned equipment. Quantity rates on larger systems could offer cost advantages not applicable in the present study despite existing tariff rates. In now selecting the system best suited to its needs, the Board can and should reserve the option of considering in the future another system that may prove more cost-effective.

REFERENCES

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APPENDIX A

VENDOR SYSTEMS

SHARED CENTREX II OFFERING

The shared CENTREX II system offered to Anne Arundel County would consist of the following:

Organization	Location (New)	Present Equipment Type-Stations	P-Primary S-Secondary Main Stations CENTREX	Present* Operators
Board of Education	Riva Road	701 PBX-175	225-P	2 1/2
Health Department	Riva Road	770 PBX-160	172-P	1 1/4
Public Works Dept.	Riva Road	701 PBX-80	100-P	
County Government	Riva Road	701 PBX-450	500-S1	6
Detention Center	Route 50	Key equipment	-S2	
Garage	Parole	Key equipment	-S3	
Library 1	Annapolis	Key equipment	7-S4	
Library 2	Annapolis	Key equipment	-S5	
Drug Center	Annapolis	Key equipment	-S6	
Courts	Annapolis	701 PBX	33-S7	
Court Annex	Annapolis	701 PBX	-S7	
Community Action Center	Annapolis	Key	35-S8	
		865	1072	9 3/4

*Present operator requirement as determined by C&P Telephone.

C&P Telephone estimates that CENTREX II will reduce operator requirements by 85%. The shared system would require 2 operators with 3 being used for the cutover and an initial period of operation of possibly several months.

All CENTREX II users would be served out of the 268 exchange. The installation would use 1250 square feet of space (25' x 50') and require 18 months for installation.

CENTREX rates are determined on a per-station basis with no charge for the number of trunks used. The rates are given for primary and secondary locations (as defined by the telephone company) and decrease for larger installations at four discrete rate-break points. The rates at present are (per month):

STATION	PRIMARY (each)	SECONDARY (each)
1-50	$17.95	$12.70
51-200	11.30	12.15
201-900	10.75	10.75
900 and up	7.45	7.45

Extensions are charged at a flat rate of $4.40 per month each.

The total cost of the system as determined by C&P (for 1054 main stations) would be $14,221 exclusive of operators and management fees. Of this amount, the allocated amount for the Board of Education's 225 main stations would be $3,215 per month.

In addition, there would be charged a one-time installation fee based only on the number of line pick-ups used. C&P Telephone did not have an estimate for this installation charge; however, assuming the number of pick-ups to be the same as the present number, which is 560,* the Board of Education installation expense would be about $8,800 (560 x $14.95 x 1.10), including Federal tax.

The main charge includes 3 operating consoles at $155 per month each.

The rate and proposal information summarized above was given to Anne Arundel County and the Board of Education by the C&P Telephone Company in October, 1972, as current at that time.

*The number of pick-ups was obtained from the Maryland C&P Telephone Company Account Information Report.

FXB-304U1 (CENTREX TYPE SERVICE)

* * * * * * * * * * * * * *

	Equipped	Maximum Capacity
Lines	300	700
Links	15	15
Attendant Console	1	3
Information Trunks	2	2
Central Office Two-Way Trunks	6	6
One-Way Out Trunks	12	20
DID Trunks	12	22
One-Line Telephones	225	

including the following features:

Camp-On Busy
Dial "1" Transfer
Busy Lamp Field
Automatic Attendant Recall
Station Hunting
Universal Nite Answer
Attendant Recall & Transfer
Direct In Dialing
Direct Out Dialing
Toll Restriction
Line Lockout
Reset Call

Cash price installed including first year's maintenance. $65,000.00

Lease
Ten year $923.00/monthly -- no installation charge

Second year's maintenance $2,400.00/yearly includes all labor and component parts necessary to keep system operational.

Floor space requirements -- H-79", W-124", D-24"

Power Requirements -- 110 VAC

No special environmental requirements

Couplers -- Two-Way Trunks ---- CDH
One-Way Out Trunks ---- CD8
DID Trunks ---- C22

Traffic -- 5.4 ccs at 400L

FXB-304U1 (PBX OPERATION)

* * * * * * * *

	Equipped	Maximum Capacity
Lines	300	700
Links	15	15
Attendant Console	2	3
Information Trunks	2	2
Central Office Two-Way Trunks	14	14
One-Way Out Trunks	0	20
One-Way In Trunks	14	14
One-Line Telephones, Dial	225	

including the following features:

Camp-On Busy
Dial "1" Transfer
Busy Lamp Field
Automatic Attendant Recall of Unanswered Calls
Station Hunting
Universal Nite Answer
Attendant Recall & Transfer
Direct Out Dialing
Toll Restriction
Line Lockout
Reset Call

Cash price installed including first year's maintenance..... $71,000.00

Lease
Ten year $1,009.00/monthly -- no installation charge

Second year's maintenance $2,400.00/yearly includes all labor and component parts necessary to keep system operational.

Floor space requirements -- H-79", W-124", D-24"

Power Requirements -- 110 VAC

No special environmental requirements

Couplers -- Two-Way Trunks ---- CDH
One-Way Out Trunks ---- CD8
One-Way In Trunks ---- CDH

Traffic -- 5.4 ccs at 400L

ITT Communications Equipment and Systems
A Division of International Telephone and Telegraph Corporation

2990 Telestar Court, Suite 107
Falls Church, Virginia 22042
Tel: (703) 560-1140

ARINC Research Corporation
ATTN: Mr. J. M. Diehl
2551 Riva Road
Annapolis, Maryland 21401

December 12, 1972

Dear Mr. Diehl:

Per our conversation, I am enclosing to you a proposal for you client's telephone system.

We have used the following as a basis for your client:

3	Cabinet TE-400A (Tel Touch)
1	Attendant Console
42	Combination Local Trunks
8	Foreign Exchange Trunks
2	WATS Lines
1	Conference Circuit
150	Single Line Telephones
100	Six Button Telephones
100	Lines Key Equipped

Cash Price: $145,000.00*

Conditional Sale:

10% Downpayment
Amount Financed
120 Monthly Payments

*Direct Inward Dialing - add approximately $10,000.

If you have any further questions, please call me on (703) 560-1140.

Sincerely,

Shelby J. Best
Sales Engineer

SJB/jsg

It should be noted that the FXB-304U1 can handle no more than fifteen internal calls simultaneously. The probability of not being able to complete an internal call based on data taken during the survey period was calculated as follows:

$$P_B = \frac{\frac{(7.69)^{15}}{15!}}{\sum_{n=0}^{15} \frac{(7.69)^{15}}{n!}}$$

$$= .007$$

or less than one call in a hundred will not be completed at a traffic load of 277 CCS* per hour.

Even though the capacity of the EPABX TE400A is somewhat higher than that of the FXB-304U1, as calculated above, the difference is not enough to noticeably improve service.

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* 277 CCS is equivalent to 7.69 Erlangs

APPENDIX B

COST ANALYSIS OF SIX SYSTEMS

COST ANALYSIS OF SIX SYSTEMS

The cost comparison curve for the CENTREX system (Figure 4-1) is based on a prorated share of the total number of lines (1054) rather than 225 lines at the primary CENTREX location as calculated by the telephone company. Thus the estimated total system cost from the telephone company was $14,221, a and the prorated Board of Education's share forecast for analysis purposes is:

$$= \frac{225}{1054} \times 14,221$$

$$= \$3,036$$

It was further assumed that telephone company rates would increase 3 percent each year over the next fifteen years. An installation cost of $8,800 was added for the first year since this is normally paid within ninety days. Ten percent Federal tax was included in the monthly recurring charge.

In order to estimate the monthly recurring charges for a privately owned system, rates were obtained from the C&P Telephone Company of Maryland and from ITT (based on their experience with the Virginia C&P Telephone Company).*

Number of DID Stations	Installation Charge (estimated)	Recurring Monthly Charge (estimated)
1st 100 lines	$625	$300
2nd 100 lines	$500	$250
3rd 100 lines	$ 25	$ 30

Interconnect Device	Installation (estimate)	Recurring Monthly Charge (estimate)
C22 (DID Trunks)	none	$8.00
CDH (2 way Trunks)	none	$6.60

Lines	Installation Charge	Recurring Monthly Charge
per line	none	$27.45

*As of this report, there is no tariff provision for direct in-dial lines in Maryland with the exception of certified military installations.

For 225 DID main stations, the installation charge would be:

= $625 + $500 + $25

= $1150

which was added to the first-year cost.

The monthly recurring charge was calculated for 225 DID main stations served by 50 trunks as follows:

= (50) ($8.00) + (50) ($27.45) + $300 + $250 + $30

= $2352.50 per month

or $2588 with Federal tax.

It was assumed that this base rate would increase three percent each year for the next fifteen years. Thus the cumulative recurring charge, principal and interest for the equipment amortized over ten years, and installation costs were totaled to arrive at the cost curves in Figure 4-1 for the TE-400A and FXB-304U1.

Modified UBC FXB-304U1 Cost

The proposed UBC system ($65,000) did not include sufficient trunk capacity (54 lines); therefore, the following adjustments were made:

Cost of the proposed system	$65,000
less 25 single line instruments at $70 each	-1,750
plus 100 key instruments at $175 each	+17,500
plus 10 DID trunks and 8 one way trunks	6,500
	$87,250

This system, financed through UBC for 10 years, would cost the user $1239 a month plus maintenance after the first year. Monthly recurring telephone company charges must also be added to this figure.

Installation charges for telephone trunks and interconnect devices were added to the first year's costs.

ITT EPABX-TE400A Cost

This system was estimated by ITT at $145,000 including 50 trunks, 200 main stations, and 100 key instruments. Financed over a ten-year period, the monthly recurring cost would be $1689. Ten percent down, or $14,500, is required under this arrangement and is added into the first year's cost along with telephone company installation costs. A monthly recurring charge for telephone company services must be included with maintenance charges (after the first year) to determine the total monthly recurring charge.

MAINTENANCE COSTS

ITT Maintenance rates were quoted under two available contracts:

(A) $15 per station plus $8 per line, all parts and labor included, or

(B) $32 per four-hour call and $11 per each additional hour plus parts.

UBC rates for a time-and-materials contract were quoted at $20 per hour plus parts or a flat $2400 per year including parts and labor.

Different assumptions were made for each of the three DID systems in order to arrive at reasonable figures for cost-comparison purposes. Maintenance for the EPABX-TE400A was calculated on a time-and-materials basis, assuming two days a month with a 10% additional charge for parts. A straight maintenance contract is probably more cost-effective than the time-and-materials contract for the FXB-304U1 and was therefore used as the basis for recurring maintenance charges. In both cases it was assumed that costs would increase three percent each year after the first year of the contract. The telephone company does not charge for maintenance.

FXB-304U1 Maintenance $2,400 per year

EPABX-TE400A Maintenance

$32 + 4 ($11) = $76 per 8-hour call

$76 per call x 26 calls per year = $1,976

$1,976 per year plus $198 for parts = $2,174 per year

C&P TELEPHONE CENTREX II* COST ANALYSIS

Year	Yearly Recurring Charge with 3% Increase Each Year and 10% Federal Tax	Cumulative Investment Including Installation Cost ($8,800)
1	$40,075	$ 48,875
2	41,278	90,153
3	42,516	132,669
4	43,791	176,460
5	45,105	221,565
6	46,458	268,023
7	47,852	315,875
8	49,287	365,162
9	50,766	415,928
10	52,289	468,217
11	53,857	522,074
12	55,473	577,547
13	57,137	634,684
14	58,851	693,535
15	60,617	754,152

* Centrex II shared with Anne Arundel County government and prorated by number of main stations.

CUSTOMER OWNED DID SYSTEM COST [1]
ANALYSIS
(Maintenance and Other Recurring Charges Included)

Year	FXB-304U1 [2]	EPABX TE400A [3]
1	47,070	66,967
2	96,321	121,389
3	146,605	176,836
4	197,950	233,338
5	250,391	290,928
6	303,957	349,637
7	358,685	409,499
8	414,610	470,551
9	471,766	532,825
10	530,190	596,359
11	575,053	640,927
12	621,264	686,834
13	668,860	734,116
14	717,884	782,817
15	768,378	832,980

[1] Based on 50 trunks between central office and customer premises, 200 single-line instruments, and 100 key instruments.

[2] United Business Communications, purchase price $87,250 ($14,867 per year financed). Maintenance based on $2400 per year flat rate, increasing 3% each year after the second year.

[3] International Telephone & Telegraph, purchase price $145,000 (10% down and $20,264 per year financed). Maintenance based on an 8-hour service call every two weeks with 10% for parts. Rates after the second year increase at 3% each year.

CUSTOMER OWNED DID SYSTEM CUMULATIVE
COSTS NOT INCLUDING RECURRING INTERCONNECT AND
STATION NUMBERING CHARGES*

Year	FXB-304U1 [1]	EPABX TE400A
1	32,984	52,881
2	69,181	93,979
3	105,471	135,702
4	142,681	178,069
5	180,562	221,099
6	219,132	264,812
7	258,413	309,227
8	298,429	354,370
9	339,198	400,257
10	380,743	446,912
11	408,221	474,095
12	436,526	502,096
13	465,678	530,934
14	495,705	560,638
15	526,632	591,234

* Identical to the customer owned DID System Cost Analysis except that recurring tariffs on interconnects and station numbering have been omitted to show the effect of these charges on the total system cost. The installation cost for these interconnects was also omitted.

PBX COST ANALYSIS

C&P Telephone Bell System 770 PBX

225 main stations	$2,645 per month
3 operators	$1,773 per month
	$4,418 per month

UBC FXB-304U1 (PBX)

225 main stations (financed for 10 years)	$1,093 per month
14 2-way trunks	477 per month
20 one-way out trunks	644 per month
16 one-way in trunks	439 per month
3 operators	1,773 per month
	$4,426 per month

The estimated monthly cost of using the ITT EPABX-TE400A was $4,992, including finance charges.

APPENDIX C

TELEPHONE SURVEY FORMS

Telephone Survey Forms

Two forms were submitted to the Board of Education to gather telephone usage data. Form A was distributed to each office to be placed near every telephone instrument. All outgoing calls were logged on the form by the person making the call. The estimated number of intercom calls and outside calls for the new facility was determined from the totals on this form. Form B was used by the Board's telephone operators to log the number of incoming calls and the time and duration of outgoing calls on the FX lines.

FORM A

Location: _____ Date: _____

Telephone No.: _____

Extension: _____

Outgoing Telephone Call
Recording Form*

Number of Internal Calls	Number of Inter-Board of Education Calls	Number of Other Local Calls (schools, personal, etc.)	Number of Long Distance Calls	Outside Trunks Busy

* Enter a mark (l) in the appropriate column each time a telephone call is placed.

FORM B

Anne Arundel County
Board of Education
Voice Communications Study

Location: _____ Date: _____

INCOMING	OUTGOING				
Indicate Incoming Call by a Mark (1)	Approximate Time of Call	Approximate Duration of Call	Baltimore Tie-Line (Check Mark)	Washington Tie-Line (Check Mark)	WATS Area Code of Number Called

APPENDIX D

C&P TELEPHONE TOLL CHARGES FOR THE 1971-1972 SCHOOL YEAR

The following charges were billed to the various Board of Education facilities during the 1971-1972 school year. These charges were used to determine seasonal variations in telephone traffic as well as adjustment factors for the period of the traffic survey conducted by ARINC Research Corporation. Only charges for calls and telegrams were used; service and equipment charges were excluded.

GREEN STREET

1971 - 1972

19 August - 18 September	$308.26
19 September - 18 October	250.72
19 October - 18 November	211.90
19 November - 18 December	175.39
19 December - 18 January	191.62
19 January - 18 February	282.31
19 February - 18 March	254.60
19 March - 18 April	209.85
19 April - 18 May	224.02
19 May - 18 June	214.40
19 June - 18 July	268.58
19 July - 18 August	342.04
19 August - 18 September	256.51
19 September - 18 October	-
19 October - 18 November	189.07

ANNEX

1971-1972

19 August - 18 September	$217.56
19 September - 18 October	142.57
19 October - 18 November	209.18
19 November - 18 December	140.70
19 December - 18 January	134.89
19 January - 18 February	202.97
19 February - 18 March	180.21
19 March - 18 April	205.77
19 April - 18 May	242.10
19 May - 18 June	366.20
19 June - 18 July	249.35
19 July - 18 August	188.25
19 August - 18 September	262.69
19 September - 18 October	-
19 October - 18 November	266.19

ARNOLD

1971-1972

(Purchasing)

11 August - 10 September	$15.61
11 September - 10 October	9.66
11 October - 10 November	6.92
11 November - 10 December	11.31
11 December - 10 January	19.92
11 January - 10 February	17.32
11 February - 10 March	17.08
11 March - 10 April	7.65
11 April - 10 May	6.69
11 May - 10 June	13.07
11 June - 10 July	8.26
11 July - 10 August	16.23
11 August - 10 September	20.09

ARNOLD

1971-1972

(School Services)

1 August - 31 August	$ 36.27
1 September - 30 September	49.92
1 October - 31 October	38.78
1 November - 30 November	32.23
1 December - 31 December	32.77
1 January - 31 January	53.52
1 February - 29 February	38.67
1 March - 31 March	46.05
1 April - 30 April	35.99
1 May - 31 May	36.14
1 June - 30 June	30.94
1 July - 31 July	26.84
1 August - 31 August	58.35

PASADENA

1971-1972

13 August - 12 September	$ 27.13
13 September - 12 October	35.13
13 October - 12 November	41.34
13 November - 12 December	27.64
13 December - 12 January	24.66
13 January - 12 February	39.02
13 February - 12 March	39.92
13 March - 12 April	37.81
13 April - 12 May	19.20
13 May - 12 June	19.62
13 June - 12 July	17.54
13 July - 12 August	15.63

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) 0631-01-1-1204	2. GOVT ACCESSION NO. (2) Rept. for Oct-Nov 72 on Phases 1,
4. TITLE *(and Subtitle)* (6) Anne Arundel County Board of Education TELEPHONE COMMUNICATIONS STUDY.	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER 0631-01-1-1204
7. AUTHOR(s) (10) W.M. Kolb	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARINC Research Corp. 2551 Riva Road Annapolis, Maryland 21401	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 79p.
11. CONTROLLING OFFICE NAME AND ADDRESS ANNE ARUNDEL COUNTY BOARD OF EDUCATION ANNAPOLIS, MARYLAND	(11) 12. REPORT DATE Dec [redacted] 72 13. NUMBER OF PAGES 42
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* ANNE ARUNDEL COUNTY BOARD OF EDUCATION ANNAPOLIS, MARYLAND	15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT *(of this Report)* UNCLASSIFIED/UNLIMITED	DISTRIBUTION STATEMENT A Approved for public release Distribution Unlimited
17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*	
18. SUPPLEMENTARY NOTES	
19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*	
20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*	

400 247

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